



Variability in late Holocene shellfish assemblages: the significance of large shore barnacles (*Austromegabalanus cylindricus*) in South African West Coast sites

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ABSTRACT

The archaeological significance of barnacles has been documented in several places around the world, but this remains to be realised for South Africa. In the absence of local ethnographic observations, it was proposed that large barnacles (*Austromegabalanus cylindricus*) were taken to campsites attached to large black mussels (*Choromytilus meridionalis*) as part of scavenged beach-stranded fauna. Basic observations available until recently for South African West Coast shell middens showed that the presence of large shore barnacles is chronologically patterned. Some hints regarding transport decisions were also apparent. This paper examines the variability in large barnacle abundance through time and space using mollusc and crustacean shell samples from eight late Holocene sites situated at different distances from rocky shorelines. Modern knowledge on the ecology of collected species is used to interpret inter-assemblage variability. This study shows that barnacle abundance depends on at least three aspects, namely: the degree of wave exposure from which barnacles and other shellfish were collected, possible shifts in the main season of shellfish collection in the last 1700 years, and field processing before transporting shellfish loads to camps.

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1. Introduction

Darwin's thorough taxonomic study on extant South American barnacles (Cirripedia) addressed several problems at the forefront of contemporary natural history and provided him with an important empirical basis for discussing the principles of natural classification in the *Origins of Species* (Barlow, 1958: 118). Scientific rewards on the same subject of study have been much less substantial in coastal shell midden research, although shore barnacles are receiving some attention as of late and appear to have been a resource of limited and variable importance to Holocene human groups (Álvarez-Fernández et al., 2010, 2013; Cannon et al., 2008; Flores et al., 2010; Gutiérrez-Zugasti, 2011; Jerardino et al., 1992; Méndez, 2002; Moss and Erlandson, 2010; Sullivan, 1987; Ulm, 2006). Evidence for their consumption has been inferred either through their regular presence in coastal sites, burning of body parts and/or reliable ethnohistoric accounts (Álvarez-Fernández et al., 2010; Bittmann, 1986; Moss and Erlandson, 2010).

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Barnacles today are regarded as a delicacy and can fetch relatively high market prices (Álvarez-Fernández et al., 2010; López et al., 2012). Whale barnacles, on the other hand, were probably not eaten but they are useful archaeological proxies for the consumption of whale meat and/or blubber in the absence of whale bones (Álvarez-Fernández et al., 2014; Avery et al., 2008; Jerardino and Marean, 2010; Jerardino and Parkington, 1993; Kandel and Conard, 2013; Moss and Erlandson, 2010; Piana et al., 2007).

While large shore barnacles encountered in archaeological contexts of North and South America and Europe have received limited attention from zooarchaeologists, the significance of this resource for coastal southern African Khoisan groups in the past is even much less understood. For instance, archaeologists working on South Africa's West Coast (Elands Bay and Lamberts Bay areas, in particular) have been aware that the presence of large shore barnacles (*Austromegabalanus cylindricus*) is chronologically patterned (e.g., Horwitz, 1979; Parkington et al., 1992; Yates, 1989) but this trend was unexplained. Moreover, whether large barnacles were eaten was never explicitly discussed, but Buchanan's (1988) dietary reconstructions for West Coast sites seem to imply that this was not the case as this taxon is not included in his calculations.

Only traces of other shore barnacles are present in South African West Coast sites of late Pleistocene and early/mid-Holocene age and these belong to small intertidal species (e.g., *Tetracita serrata*, *Octomeris angulosa*) that often grow on rocks and molluscs collected as food (Avery et al., 2008; Parkington, 2003; own data). Large barnacles (hereafter referred to as 'barnacles'), on the other hand, become a regular feature only in late Holocene shell middens dating to the last 2000 years (Horwitz, 1979; Yates, 1989; Jerardino, 1997, 2003; Jerardino et al., 2009a; Tonner, 2005). An initial evaluation of inter-assemblage variability suggests that transport decisions appear to have affected their material representation in local assemblages (Jerardino, 1997).

A large and diverse set of observations on shellfish assemblages from the Elands Bay and Lamberts Bay areas has been generated over the last 35 years. This database allows for a more detailed study of barnacles in archaeological sites and their significance to pre-colonial Khoisan groups than previously undertaken. Consequently, the objective of this paper is to do so through the analysis of faunal assemblages from eight archaeological sites located along this coastline (Fig. 1). Inter-assemblage variability is examined with a strong grounding on the ecology of collected species and consideration to collecting strategies and transport decisions.

2. *Austromegabalanus cylindricus*: biology and ecology

Very little is known about the ecology and biology of *A. cylindricus* other than its taxonomy and classification (e.g., Henry and McLaughlin, 1986; Pitombo, 2004). *A. cylindricus* is a crustacean of the Cirripedia class and occurs from Port Nolloth on the West Coast of South Africa to Port Elizabeth on the Eastern Cape (Fig. 1). It is usually 30–40 mm tall, but can grow to a height of 150 mm. It has a calcareous base and six white to pink shell plates, with the tips of the opercular plates projecting up through the aperture like 'fangs' (Fig. 1c). It is usually found only in the infratidal zone and subtidally to depths of at least 20 m. It grows often solitary, but sometimes forms clusters on rocks, on other large mollusc shells, ships' hulls or on floating structures (Branch et al., 2007; Day, 1974). Currently, their geographic distribution seems irregular, as recent reconnaissance by specialists revealed more findings near Cape Town and less so further north (C. Griffiths personal communication, April 2014). As a filter-feeder, barnacle biomass in general is significantly more abundant (up to an order of magnitude) in exposed shores versus those that are sheltered primarily because of the increased supply of food particles facilitated by greater wave action in these environments (Bustamante and Branch, 1996; Bustamante et al., 1995, 1997).

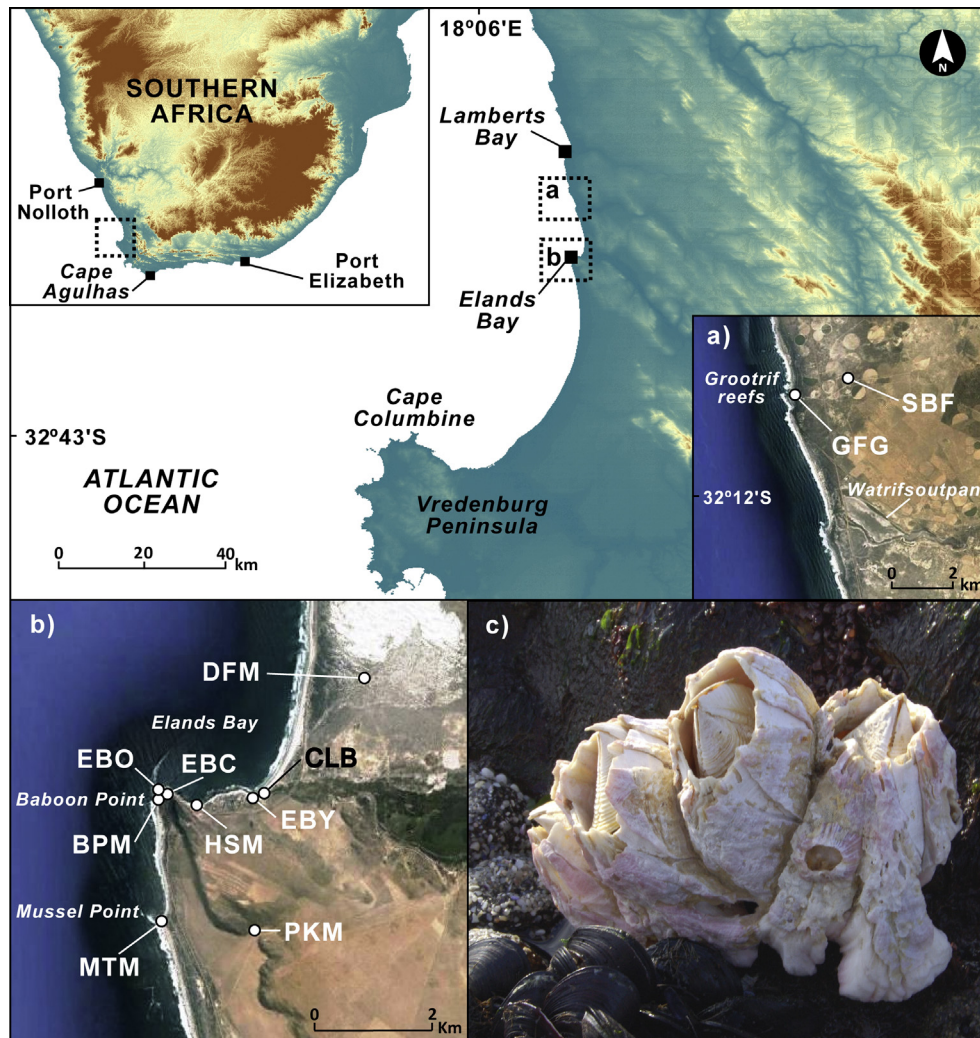


Fig. 1. Geographic setting and location of research area; a) and b) sites and places mentioned in the text: Borrow Pit Midden (BPM), Dunefield Midden, DFM; Elands Bay Cave (EBC), Elands Bay Open (EBO), Grootrif G (GFG), Mike Taylor's Midden (MTM), Pancho's Kitchen Midden (PKM), Spring Cave (SC), Steenbokfontein Cave (SBF), and Tortoise Cave, TC; c) *Austromegabalanus cylindricus* barnacles growing in infratidal zone (photograph by Charles Griffiths). Aerial photographs and maps are from Google Earth and SRTM (v4.1), processed by CGIAR-CSI (<http://www.cgiar-csi.org>).

The rocky shore shellfish community of the study area (Fig. 1; Elands Bay and Lamberts Bay) follows the distributions of species richness and biomass reported for equivalent shores elsewhere on the West Coast (Branch and Griffiths, 1988; Bustamante and Branch, 1996; Bustamante et al., 1995, 1997). An early and preliminary ecological survey by Rebelo (1982) found that the flat exposed reef of Mussel Point south of Elands Bay supports a large biomass of filter-feeders dominated by a mosaic of mussels. The more sheltered reefs within Elands Bay, on the other hand, are dominated by limpets and have a total estimated shellfish biomass one order of magnitude smaller than that of Mussel Point. West-facing Baboon Point is steep and exposed to wave action and its rock surface is extensive but only patchy mussel and limpet beds grow there, the accessible biomass being equivalent to 25% of that of the Bay reefs (Fig. 1b). Situated about 16 km north from Baboon Point, the double-convex reefs of Grootrif form a protected rocky bay and sandy cove between them (Fig. 1a). No ecological survey has yet been undertaken there, but dense limpet colonies are accessible at mid-tidal levels, and clusters of mussel beds are more common on the outer and more exposed fringes of these reefs (personal observation, 30 March 2014). Although barnacles in general were not addressed in Rebelo's (1982) study, the trophic structure of rocky shores in the study area ought to be like in the rest of the West Coast which is conditioned by the intensity of wave action (Bustamante and Branch, 1996; Bustamante et al., 1995, 1997). Hence, the biomass of *A. cylindricus*, along with that of other barnacles, is most likely to be highest at Mussel Point when compared to the protected reefs of Elands Bay and Grootrif.

3. Barnacle procurement

In the absence of any ethnographic account on West Coast shellfish gathering practices, *A. cylindricus* barnacles were initially thought to have been taken to campsites attached to large black mussels (*Choromytilus meridionalis*) after these were collected as stranded fauna (Parkington et al., 1992: 67; Tonner, 2005). Whether or not barnacles were also consumed or simply left behind as unwanted low-utility waste is uncertain and has never been investigated. The visible shapes of mussel shells on some of the attachment bases of barnacles lent support that this species arrived to sites clinging on black mussel shells. While recent work has confirmed statistically the positive association of large *C. meridionalis* modal sizes and percentage barnacles in archaeological assemblages, stranded mussels seem unlikely to have been the only or main source of *A. cylindricus* as shown by the near absence of these barnacles in modern beached material (Jerardino, 2014). Moreover, due to their low-yields and unpredictability, beached mussels appear to have contributed very little to the archaeological record. Diving to procure for black mussels with barnacles on them and other molluscs appears not to have been the case given the lack of evidence for water crafts and scant osteological indications for such an activity in precolonial times (Jerardino et al., 2013a: 2). But further and new observations that shed light on the procurement of barnacles and their contribution to the archaeological record are presented in the results section.

4. Methods

The shell assemblages used in this study date to the last 4400 years and are from eight sites: Borrow Pit Midden (BPM), Elands Bay Cave (EBC), Elands Bay Open (EBO), Grootrif G (GFG), Mike Taylor's Midden (MTM), Pancho's Kitchen Midden (PKM), Steenbokfontein Cave (SBF), and Spring Cave (SC) (Fig. 1b; Table 1). Their artefactual contents and site features suggest an important

residential component at each of them and with variable occupation spans.

The abundance of South African West Coast barnacles have been routinely reported in terms of shell weight and derived percentages rather than Minimum Number of Individuals (MNI) because of the difficulty in establishing MNIs from their remains due to their fragmentary state, including their countable parts (*terga* and *scuta*) (e.g., Buchanan, 1988; Jerardino et al., 2009a; Tonner, 2005). Also, these small and fragmentary countable pieces appear underrepresented when compared to the much larger shell weights associated with them. The same method for retrieving barnacle and mollusc shell remains has been applied since the early excavations in 1970s, namely dry sieving before they are studied further in the laboratory. All sites dealt with here were excavated following natural stratigraphy, and almost all shell assemblages discussed here were sieved through a 1/8 inch (3.2 mm) mesh. A few samples from Elands Bay Cave were sieved through a 1/2 inch mesh (12.7 mm) (Table 1). Comparison between samples is, however, not compromised as barnacle fragments are almost always larger than the biggest mesh size ever employed.

Percentages of barnacles are routinely calculated relative to the weight of all species in a sample ($[\text{barnacle weight/weight of species in sample}] \times 100$). For the purpose of this study, a barnacle index is also established as a function of the joint weight of mussels and barnacles ($[\text{weight of barnacles/weight of mussels + barnacles}] \times 100$) as the latter seem to have been procured as epibionts attached to the former species. This index also offers a check on barnacle abundances independently of the contributions of taxa other than barnacles and black mussels.

In addition to barnacle abundances, average percentage weight of low-intertidal limpets (*Scutellastra argenvillei* and *Scutellastra barbara*) and subtidal limpets (*Scutellastra cochlear*, *Cymbula miniata* and *Cymbula compressa*) were calculated ($[\text{limpets weight/weight of all species in sample}] \times 100$) as they are helpful proxies for determining the vertical tidal extent of mollusc procurement. Percentage weights of *C. meridionalis* mussels ($[\text{mussel weight/weight of all species in sample}] \times 100$) were also determined for comparative purposes. Spearman Rank Correlation tests were run with a free online statistics software (v1.1.23-r7) (Wessa, 2013).

In order to evaluate possible transport decisions, distances between foraging localities and campsites were established using aerial photos and measuring at least four different stretches between sites and their nearest rocky reef(s) (as the crow flies) and averaged. For Spring Cave (SC), situated about 100 m above mean sea level (Fig. 1b), the tract of slope below this site was included in the computations.

5. Results

The barnacle record in the study area shows striking patterns. These are evident spatially (between sites close to different types of shorelines), chronologically, and in terms of distances from the coast. Table 1 show descriptive statistics on the abundance of black mussels, barnacles, and low intertidal plus subtidal limpets for eight radiocarbon dated Holocene sites situated at different distances from the coast and associated with different types of shorelines (Fig. 1). In order to understand these patterns and the factors behind them, further insights into the way *A. cylindricus* barnacles made their way to archaeological sites are presented first.

5.1. Mode of procurement

If barnacles were collected when black mussels were procured, then higher quantities of *A. cylindricus* ought to be expected when large quantities of *C. meridionalis* mussels were collected. In order

Table 1

Average percentages of black mussels, barnacle and low intertidal plus subtidal limpets from eight West Coast sites in association with shorelines with different degree of wave exposure. Barnacle weight percentages are calculated with all species included (% weight). The barnacle index is calculated as a ratio of barnacle weight from the total joined weight of mussels and barnacles only ([weight of barnacles/weight of mussels + barnacles] \times 100). Percentages of low intertidal and subtidal limpets are established with all species identified in samples. Wherever possible and for comparative purposes, Elands Bay Cave data were obtained from samples sieved with a 0.125 inch (3.2 mm) mesh. Samples sieved with a 0.5 inch (12.7 mm) mesh are indicated with an asterisk (*). Radiocarbon dates are not calibrated.

Type of shoreline	Site	C14 age (BP)	Samples analysed (n)	Average distance from reef (m)	Average % black mussels (weight)	Average % barnacles (weight)	Barnacle index	Average % low intertidal + subtidal limpets	Average % subtidal limpets only
Sheltered	SC	460 \pm 40	10	825	21.1	0.7	3.2	0.8	0
Sheltered	SC	840 \pm 40	12	825	20.3	1.0	5.9	1.0	0
Sheltered	SC	1150 \pm 50	6	825	43.7	2.1	5.3	0.8	0
Sheltered	SC	2970 \pm 60	5	825	81.6	0.6	0.7	1.2	0
Sheltered	SC	3510 \pm 60	3	825	64.0	0.2	0.3	0.3	0
Semi-exposed	GFG	690 \pm 40	20	615	11.7	0.4	3.9	43.1	0.9
Semi-exposed	GFG	2380 \pm 60	5	615	94.0	0.4	0.4	0.9	0
Semi-exposed	SBF	2200 \pm 50	11	2600	78.3	0.7	0.8	1.6	0
Semi-exposed	SBF	2360 \pm 45	9	2600	82.8	0.3	0.3	0.4	0
Semi-exposed	SBF	2510 \pm 50	8	2600	86.3	0.2	0.2	0.8	0
Semi-exposed	SBF	2490 \pm 50–2690 \pm 60	11	2600	84.8	0.2	0.3	0.9	0
Semi-exposed	SBF	3510 \pm 60–3640 \pm 60	10	2600	63.7	0.3	0.4	6.0	0
Semi-exposed	SBF	3990 \pm 60	9	2600	54.8	0.2	0.3	6.2	0
Sheltered & exposed	BPM	640 \pm 50	22	185	67.3	18.1	21.2	0.6	0
Sheltered & exposed	EBO	590 \pm 50	8	430	52.2	7.5	13.9	3.3	0.1
Sheltered & exposed	EBO	705 \pm 50	6	430	63.9	8.1	11.2	1.8	0
Sheltered & exposed	EBO	1470 \pm 50	5	430	66.7	4.2	5.9	2.9	0.4
Sheltered & exposed	EBO	2920 \pm 60	4	430	78.5	1.2	1.5	3.2	0
Sheltered & exposed	EBC	320 \pm 50	6	725	63.9	6.1	9.0	0.5	0
Sheltered & exposed	EBC	500 \pm 45	4	725	73.2	8.0	9.9	0.1	0
Sheltered & exposed	EBC*	1120 \pm 85	11	725	69.4	10.6	13.1	3.0	0.1
Sheltered & exposed	EBC	1660 \pm 40	4	725	64.8	5.6	7.8	0.1	0
Sheltered & exposed	EBC	3780 \pm 60	5	725	86.7	1.2	1.6	0.3	0
Sheltered & exposed	EBC*	3940 \pm 60–4370 \pm 60	10	725	84.0	0.5	0.6	1.9	0
Exposed	PKM	570 \pm 20	6	1680	73.2	8.8	10.8	2.3	0.1
Exposed	PKM	880 \pm 50	3	1680	91.4	2.3	2.5	0.1	0.0
Exposed	PKM	2640 \pm 60	5	1680	98.9	0.2	0.2	0.0	0.0
Exposed	PKM	2940 \pm 20	5	1680	98.2	0.2	0.2	0.0	0.0
Exposed	PKM	c. 3000	3	1680	97.1	0.5	0.5	0.0	0.0
Exposed	PKM	3060 \pm 60	5	1680	98.5	0.4	0.4	0.0	0.0
Exposed	MTM	985 \pm 25	2	210	67.5	29.3	10.5	0.1	0.0
Exposed	MTM	1735 \pm 30	3	210	86.2	5.7	5.7	0.6	0.0
Exposed	MTM	c. 2000	3	210	97.4	2.1	2.1	0.1	0.1
Exposed	MTM	2160 \pm 50	1	210	95.3	4.4	4.4	0.0	0.0
Exposed	MTM	c. 2200	2	210	96.3	5.6	5.6	0.1	0.1
Exposed	MTM	2220 \pm 60	1	210	98.4	1.1	1.1	0.0	0.0
Exposed	MTM	2270 \pm 25	1	210	79.2	13.6	14.7	0.1	0.1
Exposed	MTM	2340 \pm 60	1	210	98.9	0.8	0.8	0.0	0.0

to determine this association, a Spearman Rank Correlation test was run with percentage weight data from these two species. No statistical significance was found when all archaeological samples were considered ($r_s = 11,738.39$, $p = 0.2514$) or when data was restricted to assemblages with highest percentages of barnacles (Table 1: assemblages within 620 m from the coast and dated to the last 1700 years) ($r_s = 474$, $p = 0.2534$).

Because *A. cylindricus* and the limpets species considered here are common in the low intertidal and subtidal zones, these taxa might have been collected with co-varying intensity in the past. Nevertheless, Spearman Rank Correlation tests found no significant association between their respective percentages when the entire set of samples (Table 1) were considered ($r_s = 2368.37$, $p = 0.1617$) or when data was limited to samples with the highest percentages of barnacles as above ($r_s = 105.12$, $p = 0.5479$).

Sampling considerations, however, need to be weighed in order to explore further the association of low-intertidal and subtidal limpets and barnacles. For instance, computing faunal data (i.e., averaging) together from successive depositional events that make a larger stratigraphic layer can potentially blur behavioural signatures that otherwise could inform on mollusc procurement during the deposition of such layer. If available, separate sets of observations that could be attributed to earlier and later phases of shellfish

collecting rounds (e.g., during monthly low tidal events lasting a few days) during the accumulation of an occupational horizon could potentially provide more detailed and meaningful observations on foraging decisions than those based on average values for the same stratigraphic layer. Fortunately, two contemporary sites included in this study (Fig. 1: GFG and BPM; Table 1) offer such an opportunity. GFG and BPM single-component horizons were excavated into a 'Top' and 'Bottom' sub-stratigraphic units or 'sub-layers' (see Jerardino, 2007; Jerardino et al., 2009a) and mollusc data for these sub-layers are presented, respectively, in Tables 2 and 3.

Average percentages of black mussels shrink markedly between Bottom and Top sub-layers (13.7%–7.5%) in GFG, while average barnacle indices and low-intertidal plus subtidal limpet species increase, respectively, from 2.0% to 4.4% and from 34.8% to 54.8%. Percentages of subtidal limpets in particular increase noticeably from 0.9% to 1.7%. Average percentages of barnacle per total weights of samples, however, do not change (Table 2).

Trends in BPM Bottom and Top mollusc assemblages show somewhat different results (Table 3) but coherent with those of GFG. Average percentages of black mussels increase moderately between Bottom and Top sub-layers (66.5%–68.3%), and those of barnacles and low-intertidal/subtidal limpet's percentages

Table 2
Percentages of black mussels, barnacle, low intertidal plus subtidal limpets and barnacle index from several squares in Grootrif G shell midden. In these squares, the stratigraphic layer 'Patella Capping' (dated to 690 ± 40 BP, see Table 1) was split into 'Top' and 'Bottom' sub-stratigraphic units during excavations.

Strat unit	Square	Sample size (g)	Black mussels (% weight)	Barnacles (% weight)	Barnacle index	% Low intertidal + subtidal limpets	% Subtidal limpets only
Top	AA2	5104.7	4.3	0.3	6.1	58.8	0.7
Top	BB2	5522.0	5.7	0.2	4.1	62.1	2.2
Top	HH2	4228.5	9.6	0.7	7.1	42.6	0.7
Top	JJ2	11,955.0	9.7	0.2	2.1	49.5	1.3
Top	KK2	10,820.5	8.1	0.2	2.4	58.6	4.5
Top	LL2	6267.2	7.5	0.4	4.5	57.0	0.6
Average			7.5	0.3	4.4	54.8	1.7
Bottom	AA2	4000.4	5.5	0.3	4.6	35.1	0.1
Bottom	BB2	2901.7	30.6	0.3	0.9	5.9	0.3
Bottom	HH2	4273.7	8.8	0.3	3.2	52.2	2.0
Bottom	JJ2	5300.2	14.7	0.3	1.9	30.5	1.5
Bottom	KK2	11,430.0	10.3	0.1	0.1	42.8	0.6
Bottom	LL2	4568.1	12.5	0.2	1.5	42.5	0.7
Average			13.7	0.3	2.0	34.8	0.9

decrease, respectively, from 19.8% to 16.2% and from 0.9% to 0.4%. Barnacle indices also decrease from 23.0% to 19.3%. Clearly, the direction of change in % barnacles and % low-intertidal plus subtidal limpets is the inverse of that of black mussels for GFG and BPM assemblages. Hence, when shellfish collectors were reaching the lower fringes of the intertidal and shallow subtidal as indicated by associated limpet species, proportionally more barnacle mass was collected relative to black mussel weight.

5.2. Different types of shorelines

Overall, average percentages of barnacles from sites next to or with close access to exposed shores are much larger (often one order of magnitude greater) than those from sites associated with sheltered and semi-exposed reefs (Table 1). This is particularly the case for sites within 620 m from the coast and samples from stratigraphic units dating to the last 1700 years. The pattern is

opposite for low intertidal and subtidal limpets, with variable but higher values at sites close to sheltered and semi-exposed reefs. Percentages of black mussels fluctuate in samples next to sheltered and semi-exposed shores, ranging mostly between 43% and 85%, while more consistently higher values (73–98%) are recorded at sites with access to exposed reefs (Table 1). These results follow the differences in shoreline types and their expected ecological species profiles as reported in the ecological literature (see Section 2 above).

5.3. Changes through time

Barnacle remains are much more common in the last 1700 years, but apparent exceptions to this pattern are SC, GFG and Tortoise Cave (TC) (Jerardino, 1997, Fig. 1a,b; Table 1). Nevertheless, when barnacle indices are considered, abundances do indeed increase in the last 1200 years (Table 1). TC barnacle indices are marginally

Table 3
Percentages of black mussels, barnacle, low intertidal plus subtidal limpets and barnacle index from Borrow Pit Midden. In these squares and initial test pit, the stratigraphic layer 'Main Horizon' (dated to 640 ± 50 BP, see Table 1) was split into 'Top' and 'Bottom' sub-stratigraphic units during excavations. When more than one bulk shell sample was recovered from some of the squares, these are indicated in parenthesis.

Strat unit	Square	Sample size (g)	Black mussels (% weight)	Barnacles (% weight)	Barnacle index	% Low intertidal + subtidal limpets	% Subtidal limpets only
Top	K9	3928.2	65.0	16.6	20.3	0.0	0.1
Top	K10	3642.2	67.5	19.5	22.4	0.3	0.0
Top	K11	3592.7	66.4	13.7	17.1	1.3	0.0
Top (a)	L9	4660.8	80.6	12.6	13.5	0.1	0.0
Top (b)	L9	5318.2	79.0	14.4	15.4	0.2	0.0
Top (a)	L10	4015.3	66.8	21.4	24.3	0.0	0.0
Top (b)	L10	3370.3	67.0	18.5	21.7	0.9	0.0
Top (a)	L11	5115.9	70.0	10.1	12.7	0.4	0.0
Top (b)	L11	5478.0	65.5	18.3	21.8	0.3	0.0
Top	Test pit	2548.6	54.9	17.3	24.0	0.0	0.0
Average			68.3	16.2	19.3	0.4	0.0
Bottom (a)	K10	4720.5	63.5	24.4	27.8	0.4	0.0
Bottom (b)	K10	3869.0	62.9	26.5	29.7	0.0	0.0
Bottom (a)	K11	4726.7	61.9	24.3	28.2	1.5	0.0
Bottom (b)	K11	4005.1	59.4	20.6	25.7	1.2	0.0
Bottom (a)	L9	5220.0	69.6	20.1	22.4	0.1	0.2
Bottom (b)	L9	5240.2	68.5	20.8	23.3	1.0	0.0
Bottom (a)	L10	4356.7	78.3	12.6	13.8	1.0	0.1
Bottom (b)	L10	3110.6	73.4	18.5	20.1	0.7	0.0
Bottom (a)	L11	5853.7	68.0	15.7	18.7	1.3	0.0
Bottom (b)	L11	5406.4	66.8	16.8	20.1	2.5	0.0
Bottom	Test pit	1248.3	59.3	17.4	22.7	0.0	0.0
Average			66.5	19.8	23.0	0.9	0.0

higher in the last 1000 years (0.5–0.7) when compared to the preceding 3500 BP material (0.3) (data available from author), but these values are perhaps too small for building a case on them. It is noteworthy that increasing quantities of barnacles over the last 1700 years can be observed at all sites and across a range of shoreline types.

5.4. Transport decisions

Comparison of barnacle abundances between broadly contemporary sites with access to similar types of shorelines and positioned at different distances from the coast reveals that assemblages located further away from the coast have smaller quantities of this taxon (Table 1). Highest values are recorded for one of the sites closest to the coast, namely Mike Taylor's Midden (Fig. 1: MTM), and variable but somewhat high percentages are also registered among MTM assemblages before 1700 BP. Barnacles do not disappear altogether at sites most distant from the coast, such as SBF and PKM (Table 1). For other species quantified here, neither the relative abundances of *C. meridionalis* mussels nor those of low-intertidal/subtidal limpets vary with distance from the coast. As suggested before (Jerardino, 1997), barnacles were probably stripped off, although not completely, from mussel shells on which they grew before they were taken to camp sites positioned at different distances from the coast.

6. Discussion

Earlier work that emphasized only shellfish procurement to explain marked increases in late Holocene barnacle frequencies (Parkington et al., 1992; Tonner, 2005) was mainly based on observations from a single site (Fig. 1: DFM). Its claims and general assumptions have now been systematically tested with data from additional eight sites and the use of an ecological framework. As a result, three factors have been identified to explain much of the barnacle variability in the study area, namely i) different ecological settings on rocky shorelines which depend on wave exposure, ii) changes in collecting strategies through time, and iii) transport decisions. Palaeoenvironmental changes seem to have had a negligible role, though. Not only have changes in sea surface temperatures (1–2 °C) and sea levels (1–1.5 m) been relatively minor in the last 4400 years (Cohen et al., 1992; Compton, 2001), but palaeoenvironmental fluctuations in the opposite direction during the Medieval Warm Period and Little Ice Age took place when barnacles became increasingly abundant in the last 1700 years. Hence, timing in faunal trends do not seem to coincide with environmental shifts. Also, given that the barnacles concerning this study live subtidally, access to them (no matter how abundant in the infratidal) rather than their possible boosted availability is the issue.

The degree of wave exposure on shorelines nearest to archaeological sites is a reliable predictor of barnacle abundance and that of black mussels. Faunal assemblages close to exposed shores show higher percentages of barnacles and black mussels while the inverse is the case for sites near protected and semi-exposed reefs. Recent work on the basis of black mussel and limpet sizes associated with different types of shores arrived to same conclusions (Jerardino, 2014; Jerardino et al., 2009b). Hence, dominant ecological conditions at reefs play an important role in shaping the material record of nearby shell middens. Clearly, there is a need for archaeo-malacology studies, particularly in southern Africa, to engage more fully with ecological variables beyond general or basic considerations in order to maximize data interpretation (e.g., Campbell, 2008; Fa, 2008; Flores and Broitman, 2008; Giovias et al., 2010, 2013; Jerardino et al., 2014; Thakar, 2011). Other important

sources of variability in zooarchaeological assemblages, such as human predation, prey choice and foraging strategies, seasonality, and environmental changes, to name a few, are also important and need to be weighed on a case by case basis (e.g., Bird et al., 2002; Giovias et al., 2010, 2013; Jerardino et al., 2008; Whitaker and Byrd, 2012).

In broad terms, the percentages of barnacles and those of black mussel and low-intertidal and subtidal limpet abundances appear to vary independently from each other as revealed by Spearman Rank Correlation tests. Behaviourally, this would mean that neither black mussels nor low-intertidal/subtidal limpets were *always* collected with more intensity when barnacles were procured *during the entire* late Holocene. However, when greater chronological resolution is gained in depositional events of recent age (last 700 years), the relative abundance of barnacles co-vary with that of low-intertidal/subtidal limpets and with modest surges in mussel shell sizes. This suggests that shellfish collection in the last 700 years (if not earlier) was probably undertaken mostly during exceptionally low tides, taking advantage of equinox spring-low tides (known as equinoctial-spring tides). Interestingly, seasonality studies with post-1400 BP seal remains from Elands Bay point to coastal visits during spring (Woodborne et al., 1995) or onset of autumn (Fisher and Parkington, 2014), which is when such equinoctial-spring tides take place (usually around the third week of September and March, respectively, in the southern hemisphere). This timing might be related to the particular subsistence rounds of indigenous herding groups whose local presence became increasingly more frequent in the last 1700 years (Jerardino et al., 2013b). The lower barnacle frequencies before 1700 BP might well indicate that shellfish was collected throughout the year and whenever it was safe to do so because of red-tide events (Shannon, 1989). A lack of seasonal preference for shellfish gathering before 1700 BP is congruent with evidence for restricted mobility in the context of raising population densities between 3500 and 2000 BP (Jerardino, 2010, 2013).

Instead of invoking the collection of infrequently stranded subtidal black mussels with barnacles attached on them after 1700 BP as an explanation (Parkington et al., 1992; Tonner, 2005), people are likely to have targeted exceptionally low spring tides when access to subtidal fauna is greatest without diving. Recent analyses of stranded black mussels and associated fauna support this latter reconstruction (Jerardino, 2014). As the vertical extent of reefs became increasingly uncovered, barnacles and low-shore subtidal limpets became progressively more accessible to foragers, which translated into greater contributions of these species to archaeological assemblages. Likewise, the inverse direction of change in barnacles and low-intertidal plus subtidal limpets on the one hand and black mussels on the other between Bottom and Top sub-layers in GFG and BPM (Tables 2 and 3) probably reflects different phases in shellfish collection for the duration of equinoctial spring-tides. It is thus possible that GFG accumulated when low sections of reefs became increasingly visible and accessible while BPM accumulated when the lowest tide mark was rising again.

Decisions about transporting barnacles back to sites evidently depended on the distance to be travelled as illustrated by ethnographic studies (Bird and Bliege Bird, 1997; Thomas, 2002) and initial archaeological observations (Buchanan, 1988; Langejans et al., 2012). Local variability in barnacle discard at archaeological sites may well have been shaped by the trade-offs between field processing and transport, whereby barnacles could have been regarded as low-utility waste or lower-quality parts of collected black mussels (see Bird et al., 2002). Before 1700 BP, trips beyond ~200 m from the shore involved relatively thorough barnacle removal from mussels as reflected by high percentages of this

species at MTM situated close to the coast (Fig. 1) and very low numbers in more distant sites. After 1700 BP, people continued to strip barnacle off from mussels before transporting shellfish back to camp sites, but this form of field processing was somewhat partial as more barnacles arrived to all sites than before (Table 1). After 1700 BP people seem to have targeted equinoctial-spring tides, a foraging window when mussels covered more extensively with barnacles became increasingly accessible. Due to their greater (temporary) availability and robust shells, more barnacle per mussel was collected and added effort in removing barnacles was probably required before shellfish loads were taken to sites. As a result, barnacles were removed from mussels less systematically than it was the case before 1700 BP. This scenario does not eliminate the possibility that some barnacles may have been taken back to distant sites for final consumption while those removed near the shore were fed on soon after their collection.

7. Conclusions

This study shows that wave exposure, seasonal emphasis on shellfish collection, and transport decisions are important factors behind the variability in South African West Coast archaeomalacological assemblages. The benefit of regional approaches that use large and chronologically well controlled samples for understanding variability in shellfish assemblages has also been made evident. Future excavation of additional sites situated at varying distances from the coast and in association with rocky shores under different wave regimes will offer an opportunity to further test the conclusions arrived here.

The degree to which barnacle and other shellfish taxa surviving in archaeological deposits may have been differentially transported to the sites ought to be investigated further. In the absence of relevant ethnographic observations for the West Coast of South Africa, experimental measures of costs and benefits of field processing need to be developed. Foraging distances, encounter rates, acquisition efficiency, handling costs, and bulk versus processed utilities are a few of the important variables that need to be quantified in the context of local ecological setting (see Bird and Bliege Bird, 1997; Bird et al., 2002). High-resolution palaeoenvironmental data and seasonality studies via sclerochronological analyses would also be required in order to tease out the most important factors shaping local faunal assemblages. Moreover, the reconstruction of past shorelines would be mandatory for the study of assemblages dating before the time when the coastline reached its present outline c. 8000 BP, as foraging distances and type of coastal environments dominating foraging locations would have fluctuated significantly as a result of post glacial sea level rise and coastline reconfiguration. Understanding variability in archaeomalacological assemblages from South Africa and elsewhere in the world is becoming increasingly complex. Approaches now demand more exhaustive analytical methods and interpretative frameworks as well as dealing with basic practicalities such as good chronological controls, generating robust sample sizes and studying multiple sequences.

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